APPLICATION

FOR

UNITED STATES LETTERS PATENT

TITLE: INTEGRATED SENSOR

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INTEGRATED SENSORS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims benefit of U.S. Provisional

5 application no. 60/154,486, and 60/154,487, both filed

September 17, 1999.

STATEMENT AS TO FEDERALLY-SPONSORED RESEARCH

The invention described herein was made in the

performance of work under a NASA contract, and is subject

10 to the provisions of Public Law 96-517 (U.S.C. 202) in

which the contractor has elected to retain title.

BACKGROUND

It is often desirable to obtain different kinds of

15 information about particles.

One kind of information is about shear stress. An

existing method of detecting wall shear stress puts a

heated wire or element in the flow to be detected. The

rate of cooling of the element provides a measure of the

20 wall shear stress. Other similar sensors, which sense other

parameters, are also known.

However, this system by itself has certain problems.

The techniques may be intrusive, meaning that they may

effect the rate of flow. The techniques can be affected by

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contaminants in the flow. For example, certain

contaminants may deposit on the heated element and cause

the heated element to react differently. These techniques

can also change the characteristics of the sensor; hence

5   requiring calibration.

Non-intrusive optical techniques may be considered

using conventional optics. However, this results in a

bulky setup, and setup that is highly susceptible to

vibration. Moreover, the size of such a setup may cause

10   difficulty in allowing the system to be effectively used.

Other kinds of probes can be used to detect the size

of particles, and may have similar drawbacks.

SUMMARY

15   The present application teaches integrated optical

sensors for detecting particle details.

One aspect detects and/or measures wall shear stress

in flows.

20   ## BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects will now be described in

detail with reference to the accompanying drawings wherein:

Figure 1 shows a schematic for a first wall stress

sensor;

Figure 2 shows an optical fringe pattern emitted by the sensor of Figure 1;

Figure 3 shows a details of fabrication of the optical part;

Figure 4 shows an assembly drawing showing the way in which the elements are held within a housing;

Figure 5 shows another embodiment using a ...

Figure 6...

DETAILED DESCRIPTION

The present application teaches a special miniaturized and integrated optical sensor probe for measuring wall shear stress in aerodynamic and hydrodynamic flows for example. As described herein, the system also provides structure which is highly minaturizable, and which can be formed within a housing of a special type that enables the use of the sensor in harsh environments. Moreover, the system in is non-intrusive and non-invasive. The center of the probe's volume may be located very close to the surface being measured, e.g. as close as 100 microns to the surface. Moreover, the sensor as described herein may be configured in a way, as described herein, that may require less calibration.

A schematic of the sensor is shown in Figure 1. A diode laser 100 is formed on a substrate 102. The diode laser produces a diverging output beam 105 which diverges at a specified angle. The output beam is shaped, for

5   example, into two, parallel very high aspect ratio ellipses. The beam is coupled toward a transparent substrate, e.g., a quartz substrate 110 which forms an optical assembly. The quartz substrate may have a size, for example, of 600 microns thick and 700 microns square on

10   a side. The quartz substrate 110 includes a metal film 115 formed thereon, e.g., a film formed of chromium or aluminum. The metal film is processed to form specified openings therein. Optical slits are formed in an area 120 of the metal film, arranged to form a diffractive optical

15   element. The slits can be fabricated by etching the metal from the thin film in a specified pattern.

The light exiting from the diffractive optical element 120 forms a two-dimensional, linearly diverging optical fringe pattern 125. The optical fringe pattern can, for

20   example, simply include diverging fringes. The fringe pattern may be of the type shown in Figure 2 where the pattern width is on the order of 25 microns, and the position is on the order of 90 microns for the main part of

the fringe, with the edges of the fringe ending at 130 -

140 microns.

The fringe 125 impinges on a mask 130 which is formed

on the second surface 128 of the quartz substrate 110.

5   The second surface 128 of the quartz substrate is

placed near the flow to be measured. Light is scattered

off the particles crossing the fringe pattern to form

reflected beam 130.

Scattered light is also obtained by a second optical

10   window 135 that is formed in the metal film 115. The light

is collected through that optical window, via another

diffractive optical element 140 formed on the surface of

the quartz element. The scattered light is collected by

those elements and focused onto an optical fiber detector

15   145. An avalanche photodiode 150 can be located at the end

of the detector, receiving the light therefrom.

An important feature of system in Figure 1 is that the

sensor element can be fabricated using micro-fabrication

technology. The substrate 110 can be formed as shown in

20   Figure 3. The surface 112 includes the laser "lens" 120,

and the collection lens 130, 140. The other side 128 of

the substrate includes a plurality of slits. In addition,

both sides of the substrates include alignment marks. 112

include the alignment marks 312, 314, which are alignment

marks for the electronic beams. The front side 128

includes the alignment marks 316, 318 which are the

alignment for the front-to-back transfer.

The substrate may be fabricated as follows. A quartz

5   substrate of size 2mm x 2mm x 0.5mm is obtained. The

quartz substrate can be fused silica, for example. The

substrate is first evaporatively coated with a thin film of

chromium using evaporation. The result in structure is

then coated with polymethylmetachrylate or PMMA.

10   Slits 130 are opened in the front side 128. This can

be formed as two different openings, e.g., a first window

320 which is 100 microns wide and 500 microns long. A

plurality of slits 325 are formed to the side of that

window. These can be 1 - 2 microns wide, and 500 microns

15   long. The slits have 10 micron separations from one

another, and may be separated by 5 microns from the window

320. The slits and optical window pattern can be opened in

the PMMA using e-beam lithography. The chromium may be

subsequently wet edged in the open areas to form better

20   openings.

Thereafter, the surface is coated with a thick layer

of photoresist in order to protect the surface. The back

side 112 is also coated with photoresist. The front side

alignment marks are used to form front side holes and open

holes in the photoresist using an optical mask and UV

exposure. The surface is then coated with metal for

liftoff. The metal is removed using E-beam alignment

marks. All of the photoresist can also be removed.

5   A PMMA layer is then deposited on the bottom of

substrate 112. Two different diffractive optical elements

are formed in the PMMA layer. The PMMA laser lens 120 is

formed which is 200 microns wide 500 microns long. The

PMMA collection lens 135 is formed that is 400 microns wide

10   500 microns long. These are formed using E-beam

lithography and developed using acetone.

          The sensing element is then formed and mounted in a

housing 400. The housing 400 includes all of the structure

therein, including the diode laser and optical receiver.

15   This system can produce significant advantages. In

addition, modifications in this system are contemplated.

For example, a diffractive optical element can be used in

place of the optical window 320 in order to collect the

scattered light more efficiently.

20   In another embodiment, shown in Figure 5, the detector

is mounted directly on the substrate 102. This avoids the

use of fibers, and reduces the parts count. In this

embodiment, both the laser 100, and photodiode 500 are

mounted on a single substrate 102. A controller 502 may

also be mounted on the substrate. The controller may control both the laser 100 and the photodiode 500. For example, the controller can instruct the laser what and when to emit. It can receive information from the

5   photodiode, and interpret it in view of timing information sent to the laser.

Another embodiment which forms a fiber optic particle probe is shown in Figures 6a and 6b. A diode laser is used along with curved gratings and detectors. Figure 6A shows

10   a configuration with a laser 600 emitting along both sides 602 and 604. The two-sided emission provides laser output arms 606, 608. Beam 606 is reflected by mirrors 612, 614, and coupled to a curved grating 616. Beam 608 is correspondingly coupled to grating 618. The outputs 622,

15   624 of gratings 616, 618 are recombined off the surface at a point 610. The point 610, for example, can be 3 millimeters over the surface of the substrate 600. A fringe pattern is formed by the recombination.

The fringe pattern is centered on a second laser beam,

20   called the IMAX beam, that has been created by a second laser source 635. The IMAX beam provides information on the size of the particle and as such is a particle-sizing beam 620.

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Light is scattered by the particles and received by photodetectors 642, 644, which are mounted on the substrates in locations to receive the scattered light from the particles at the point 610. The phase shift of the

5   detectors is proportional to the particle size at the point 610. An on-chip or off processor or controller may receive the signals from the photodetectors and calculate the particle size.

Figure 6B shows an alternative embodiment in which

10 fringes in space are formed. A single ended diode 650 produces an output 652. The diode laser output 652 is allowed to diverge onto a curved grating 654, which is blocked in its center shown as 656.

The grating redirects the light 652 into two separated

15 light beams 660, 662, which are separated by the blocked portion 656. The two light beams to intersect 3 millimeters off the surface at the point 664. A separate laser 668 produces an IMAX beam 670. As in the Figure 6A embodiment, photodetectors 680, 682 detect the scattered

20 light and use the scattered light to find particle size.

Another embodiment shown in Figure 7 uses a phased Doppler technique without the technique using the IMAX beam. The same structure of the laser 650 and curved grating 654 forming the LDA beams intersecting above the

surface is defined.   Detectors 700, 710 are located on an arm extending above the surface to receive the beam. This technique works best for particle sizes close to the laser wavelength.

5   As in the other embodiments, the scattered light gathered by the two detectors exhibits a phase shift that is proportional to the phase particle size.

         Although only a few embodiments have been defined in detail above, other modifications are possible.

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